PATENT SPECIFICATION

673,168

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COMPLETE SPECIFICATION

Change Speed Gear of the Tiltable Roller Type

I, GERALD STRECKER, a German citizen, of Oberstrasse 13, Darmstadt-Eberstadt, Germany, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention has for its object a change speed gear operating by friction and adapted to provide a continuous change in speed ratio, of the type which includes in principle two concave faced bevel friction wheels arranged coaxially with one another with their smaller ends adjacent and serving respectively as a driving and as a driven wheel, the wheels being associated with one or more convex-faced transmission rollers engaging between them, the axes of which rollers are tiltable about centres outside the plane or planes on which the respective roller engages the wheels in planes containing the axis of the wheels, in accordance with the speed ratio desired, which ratio is determined primarily by the relative diameters of the tracks on the driving and driven wheels with which the rollers engage, and the wheels and rollers being of hard material and the concave faces of the wheels being of less curvature than the convex face of the rollers so that a substantially point contact is obtained between the rollers and wheels. The friction wheels and transmission rollers are bodies of revolution, the peripheral surfaces of which are generated by curves. The generating line of the concave section of the friction wheels will be termed hereinafter the definition generator, while, in contradistinction, the generating line of the convex face of the transmission rollers is designated hereinafter as the transmission generator.

Such change speed gears are already known and heretofore the transmission rollers, which are generally of spherical form, run permanently on a single track; in other words, the same point of the convex transmission generator is at all adjustments always in contact with the corresponding points of the concave definition generators. It has also been proposed to use transmission rollers provided with narrow projecting straight section transmission tracks, said tracks being of a hard material and being adapted to impress the softer material of the bevel wheels, or *vice versa*.

But even in the case of convex transmission generators the actual contacts are always obtained by flattening of the moving members over a surface, generally over an ellipse, so that the track on the transmission roller does not correspond to a line but to a narrow belt-like strip. One drawback of the prior embodiments is that while the operative surface to be considered changes for the definition generators at each change in the transmission ratio, it always remains the same for the transmission generator. The transmission rollers are thus permanently subjected to stresses at the same place and are fatigued much earlier than the bevel wheels. Any damage to the operative surface of the transmission rollers will, however, rapidly destroy the co-operating running surface of the bevel wheels. In order to increase the load capacity of the rotary members, it appears of advantage to equalize to a large extent the radii of curvature of the transmission and definition generators and thus to obtain a rolling track which is comparatively broad and has a corresponding load transmission capacity. However, this by no means removes the basic drawback that, in contradistinction to the bevel wheels, the transmission rollers are always subjected to stress on the same track. The pressure of the transmission rollers against the bevel wheels is limited by reason of the heat produced at the contact point due to the

[*Price*

relative movement not being a pure rolling movement. The construction generally used in practice where the definition generators are constituted by arcs of a circle described round the centre of rocking of the transmission rollers, generally has, it is true, within its range of adjustment, two positions for which tangents to the points of contact pass through the meeting point of the axes of rotation of the members rolling over one another so that the movement is then a pure rolling movement. The departure from such conditions and consequently the rubbing due to relative skewing at the points of contact become all the greater the greater is the range of adjustment required. The heating becomes the greater the larger the contact surface obtained through the pressing together of the parts rolling on one another and their elasticity, in other words, the greater the sliding paths due to the movement not being a pure rolling motion.

The development of the art has accordingly led to the use of rolling members of great hardness adapted to carry considerable loads, i.e. to surfaces of hardened alloy steel so as to keep the contact areas small. Further, in order to obtain pressure ellipses whereof the major and minor axes have lengths that are too different from one another, it has been necessary to reduce the pressure of application between the different parts, as compared for instance with that used in standard ball bearings. This reduction has become all the more necessary, in order to avoid undesirable heating at the contact points, as the range of adjustment of the change speed gear has increased with the development of the art. As heating still took place on account of movement which is not a pure rolling movement, it became necessary, in order to protect the surface hardening of the rolling paths, to use cooling means for which purpose fluid oil was used as required for lubricating the bearings. Such oil baths reduce the frictional coefficient however and consequently the load capacity of the gear. The frictional coefficient also decreases rapidly as the peripheral speed increases, due to the adherence of the oil and consequently there are limits to the increase of the speed of rotation and to the power capacity of the gear. It has also been proposed to provide change speed gears of the type disclosed with definition generators no longer constituted by arcs of a circle but by tractrices and to secure the spindles of the transmission rollers to a guideway capable of being shifted along the common axis of the bevel wheels in order to adjust the position of the transmission rollers. It was supposed that this would constrain the tangents to the definition generator for each pair of co-operating contact points, always to pass through the corresponding intersection of the axes of the transmission roller and of the bevel wheels so as to satisfy the condition for a pure rolling movement. In fact, this condition is satisfied in such gears only approximately within a very narrow range of adjustment. And even this result is obtained only through the elastic engagement of the transmission rollers, in other words, through a variable spacing with reference to their guiding point and thus by abandonment of pure rolling motion. In addition, one of the two surfaces rolling over one another, is made of elastic material. Without such resort it would only be possible to bring one of the two sides of the transmission rollers into contact with the bevel wheel, the other side interfering with the other wheel.

The arrangement for obtaining the operative pressure in recent embodiments effect not only an elastic engagement between the parts, but also pressure by a wedge action in order to adjust the operative pressure automatically in accordance with the torque. Further, pressure compensating means have been developed for ensuring the same pressure at all points of contact between the running surfaces. These arrangements are of primary importance in achieving utilisation of transmission gears of the rotary roller type and only their application has allowed the general practical use of such change speed gears. However, the stress to which the transmission rollers are subjected on one and the same running track, the reduction in the load capacity in the case of wide ranges of adjustment due to the low load capacity at the narrow end of the bevel wheels, and the necessity of providing an oil bath when hardened steel is used with the objectionable consequences of the presence of such a bath, are all limitations which remain detrimental drawbacks and considerably reduce the possibilities of application of rotary roller change speed gears.

The present invention overcomes these drawbacks by the use of transmission rollers, the operative contact points of which vary in position during adjustment, the rollers thus running on different rolling tracks at different ratios of transmission. The result is achieved primarily by giving a suitable shape to the definition generator and to the transmission generator, associated if required with further features to be disclosed hereinafter. As a transmission roller of any desired profile moving over definition

generators forming a common circular profile operates permanently along the same rolling track, it is necessary to depart from the common circular outline, as was almost exclusively used heretofore. The necessary profiles are determined as disclosed in detail hereinafter, profiles of many kinds being usable. It is possible to use for the definition generators circular arcs having separate centres for both tracks, or again circular arcs of different radii, or profiles of varying curvature. The transmission generator may comprise a curve of circular profile or a profile differing from a circular form. If it is desired to keep both contact points on the same running track for each position of the transmission roller, in other words, if the possible running tracks on the transmission roller lie in parallel planes, the definition generators must have a continuously varying curvature.

A gear with a wide zone of wear on the transmission rollers avoids the drawback of rapid fatigue of the material with its detrimental consequences for the gear. On the other hand, structural modifications of the prior art are to be expected because, as disclosed hereinafter, the law governing the shifting of the transmission rollers is no longer a mere rotation round a point on the axis of rotation of the roller but is of a more intricate nature. The roller or rollers may be constrained to move in the curved path giving correct engagement with the wheels which do not move axially. It has been found, however, that the divergences are comparatively small for suitable dimensions of the parts, so that it is possible to retain pivoting of the axes of the transmission rollers about correspondingly selected stationary axes provided certain arrangements are used which are in general in use in recent embodiments for equalising pressure between the different points of contact of the transmission rollers. This may be done by a parallel movement of the transmission rollers perpendicularly to their rolling axes or else by a rocking movement of the transmission rollers about an axis through the centre of the roller and parallel to the axis about which the roller is tilted.

In a gear according to the present invention, the operative diameter of the transmission roller varies as it is tilted out of its mid-position. If at the same time both contact points of the transmission track move outwardly, that is to the ends of a larger diameter, further advantages are obtained as regards reduction of wear and a larger range of adjustment. The points of contact or of operation on the definition generators then move more rapidly along the larger diameter on the one bevel wheel and more slowly on the smaller diameter on the other bevel wheel than would correspond to the mere tilting of the transmission roller. This results in greater distance being kept from the narrow end of the bevel wheel, which narrow end cannot carry so great a load by reason of its great curvature (small diameter). The bevel wheels can, therefore, for a given range of adjustment, be made stronger or again for the same narrow-ended bevel wheels the gear provides a larger range of adjustment. In either case, the transmission gear may be more highly loaded and therefore transmit greater power because the transmission generator when tilted works on a larger diameter. The construction according to the invention is also well adapted to satisfy strictly the conditions of pure rolling movement. The triangle formed by the line joining the two points of engagement of the transmission generator and the tangents to these two points, should for pure rolling movement always have its apex where the tangents intersect at the point of intersection of the axis of rotation of the transmission roller with the common axis of the bevel wheels and it should consist of two halves symmetrical with reference to the axis of rotation of the transmission roller. It is, therefore, necessary first to select a construction for which the two points of contact are for every position of the transmission roller on a common roller track. When the roller is tilted out of its mid-position, the apex angle of the tangent triangle decreases while the altitude of the triangle increases. Consequently, the two other angles contained between the line connecting the two points of contact and the tangents increase. If the roller track remains the same during such tilting, the required change of the angles is obviously not possible. However, if the roller track moves to another parallel plane, the points of contact in the new plane may be such that the tangent condition for pure rolling movement is satisfied. How suitable profiles for the definition and transmission generators can be obtained will be described hereinafter.

Some examples of embodiment of the invention together with a device and a method for designing and drawing the definition generator are illustrated in the accompanying drawings.

Figures 1 and 2 show a gear wherein the two points of contact of the transmission roller move in the direction of tilting of the latter, one of said points being shifted towards the larger diameter end of the roller and the other towards the

smaller diameter.

Figures 3 and 4 show a gear wherein the points of contact of the transmission roller move in the opposite direction to that of tilting, i.e. towards the smaller and larger diameter ends of the roller respectively.

Figures 5 and 6 show a gear wherein both points of engagement of the transmission roller move towards the larger diameter end of the roller as it is tilted away from its mid-position.

Figures 7 and 8 show an instrument for designing and drawing the definition generator of a change speed gear according to Figures 5 and 6.

Figure 9 shows a change speed gear the parts of which have a pure rolling movement.

Figure 10 illustrates a method of designing the definition generator in the case of such a change speed gear operating with a pure rolling motion.

Figure 11 is a diagrammatic showing of a practical embodiment of the gear according to Figures 5 and 6.

In Figures 1 to 6 and 9 to 11, the same reference numbers refer to the same parts.

Turning first to Figure 1, the references 1 and 2 designate the bevel wheels, both of which are generated by the same definition generator, and 3 designates the transmission roller; such a single transmission roller can be replaced by a plurality of rollers for instance by two rollers *3a* and *3b* as in Figure 11, and each roller is generated by the same transmission generator.

B1 and B2 are the contact or operating points where the definition and transmission generators touch for the mid-position of the transmission roller. B^11 and B^12 designate the location of said points when the roller has been tilted. S is the bearing point for the axis of rotation of the transmission roller. M1 and M2 are the centres of curvature of the definition generators of the respective wheels 1 and 2 while N1 and N2 are the corresponding centres of curvature of the transmission generator, the same letters being provided with indicia for the corresponding points in the tilted position of the roller. Further, Figures 1 to 4 show the lengths $N1S = N2S = e$, the lengths $N1\ M1 = M2\ N2 = a$, the distance between the line joining the points M1 M2 and the main axis measured perpendicularly to the latter being equal to k and the distance between the line joining the points M1 M2 and the point S measured perpendicularly to the main axis being equal to i.

Figures 1 and 2 illustrate the essential arrangement of a gear wherein the contact of the transmission roller with the bevel wheels is displaced over a wide area during adjustment instead of being restricted to a single track. In mid-position there is but a single track whereas when the roller is tilted the two contact points define different tracks on the roller. This example of the invention has the drawback that the difference in diameter of the two tracks on the roller acts as a supplementary speed-changing gear which reduces the range of adjustment of the complete gear. Such an arrangement can be used, therefore, only within a range up to a ratio of say, 1 to 6, on either side of the mid-position of the roller. The definition generator and the transmission generator are both constituted by arcs of circles. The length e in this case is greater than the length a. The points of contact move, as apparent from the drawing, in the direction of tilting of the roller.

Figures 3 and 4 illustrate a similar arrangement where the contact points of the transmission roller move in the opposite direction to that of tilting of the roller. At the same time, the difference between the operative diameters of the transmission roller arising as a consequence of tilting acts as a supplementary change of speed adding its action to that of the gear as a whole, whereby the arrangement illustrated provides, in spite of the reduced length of the contact surfaces on the bevel wheels 1 and 2, a range of ratios up to say 1 to 9.5. In this case again, the definition generator and the transmission generator are both constituted by arcs of circles. In this example the length e is smaller than the length a. Whether the distance i is additive or subtractive in relation to k is unimportant. In the above described embodiments, it is necessary to shift the bevel wheels axially when the transmission roller is being tilted for adjustment.

Figures 5 and 6 illustrate a modification in which there is a continuous change of the radius of curvature of the definition generator of the bevel wheels 1 and 2. In this case again, the transmission roller has a wide operating area, but the two contact points always move on the same track defining a plane which moves parallel with itself as the roller is tilted. Thus the position of the tangents becomes symmetrical with reference to the axis of rotation of the transmission roller. The change in curvature of the definition generator is calculated in such a manner that the tangents at the contact points always pass through the intersection of the main axis with the axis of the transmission roller, that is the movement is a pure rolling movement for all positions. While in the first two examples the bevel wheels had

to be axially adjustable, they are stationary in the present example. For this reason the axis of the transmission roller is arranged to be shiftable parallel with itself, for example by causing a surface F (Figure 5) rigid with the axis of the roller to roll on a freely rotating spindle S about which the adjustment of the roller is effected in the plane of the drawing. This allows a transverse shifting of the roller in the direction indicated by the double arrow E (Figure 5). The tilting of the transmission roller to adjust the gear ratio is effected in this case by a separate lever not shown, connected with the axis of the roller.

Figures 7 and 8 illustrate a drawing instrument of the planimeter type for drawing the definition generator of a gear according to Figures 5 and 6. The rods 1 and 3 are rigid with one another and the rod 1 carries at its end a fork 2; two similar pairs of rods 4 and 6 rigid with and perpendicular to, one another are also provided; each pair of rods 4 and 6 carries at its intersection a roller 7 having a sharp edge and freely revoluble on the axis of the rod 6. The rods 4 carry forks 5 adapted to co-operate pivotably with one another and with the fork 2. At the points N1 and N2, the rod 3 is pivotally secured to the corresponding rod 6. The rollers may be inked with printing ink fed by inking rollers not illustrated, whereby they are able to draw their paths on drawing paper laid underneath them. Now, if a pencil held at the intersection of the forks 2 and 5 is caused to move along a line AA corresponding to the principal axis of the transmission gear in the plane of the drawing, the roller 7 will draw the curve appearing in Figure 8 as shown at B1—B'1 or B2—B'2 so accurately laying out the desired shape for the definition generator. The intersection C between the rods 1 and 3 simultaneously describes the path illustrated in Figures 7 and 8. The curve thus obtained has a strong resemblance to a cycloid and has in common with the latter the property of closely approximating the arc of a circle over a comparatively considerable length. This property is made use of in respect of the above described shifting of the roller axis in relation to the axis of the bearing point shaft which is stationary in space. The axis of the bearing point shaft S in Figure 5 lies somewhat nearer the main shaft than the centre of curvature M of the definition generator at the mid-position and it lies in fact at the centre of the arc of a circle substituted for the above cycloid. Over an angle of tilt up to about 45°, it is possible to use this substitute arc without any difficulty. The practical construction may comprise a flat bearing surface carried at the end of the roller axis, as described above, which rolls in contact with the surface of the freely rotatable shaft S, or again, as in the case of Figure 11 described hereinafter, it is possible to use two plane surfaces sliding over one another.

Another possible method for accurately drawing the definition generator is illustrated in Figures 9 and 10. In contradistinction to Figures 7 and 8, the axis of rotation of the transmission roller is supposed to be capable of tilting about the stationary point S without any shifting of the axis parallel with itself. The outline of the definition generator is obtained as follows:—For the different positions of the transmission roller, the tangents to said roller are drawn, taking into account the conditions which govern a pure rolling movement, namely that these tangents must pass through the intersection of the axes of the two parts rolling on one another. It is thus possible to obtain, starting from the tangents and by integration, surfaces enveloping the desired outline, the integration being effected in the present case graphically. In Figure 10 the points M1, M2, etc. are typical of the required intersections of the tangent from the corresponding points T1, T2, etc. with the axis of the roller and the axis yy of the wheels. The lines $a1$, $a2$, $a3$ are typical of lines parallel to the axis yy upon which the tangent point must be located when the roller is in contact with the wheel. Across each of these lines is drawn a series of short lines parallel to the corresponding tangent. A smooth curve can then be drawn such that it crosses each of these lines $a1$, etc. in the same direction as the corresponding set of parallel lines. Such a smooth curve is the required profile and is indicated by $T1^{11}$, $T2^{11}$. D1, D2, D3 are corresponding positions of the mid point of the outer face of the roller. $a1$, $a2$ are corresponding angles of tilt. C is the centre about which the adjustment is made, and xx the axis of the roller in mid position. The curve obtained has a certain apparent similarity with that of Figures 5 and 6, although it represents a different mathematical function. The increase of the curvature from the inner end to the outer end is more rapid. In this case the bevel wheels 1 and 2 must be shifted axially during adjustment.

The possibilities of laying out the generator of the bevel friction wheels are by no means exhausted by the examples given above. Above all, it is possible to carry out both methods not only graphically but also analytically.

The curves described and illustrated for generating the surfaces of the friction wheels are only a few of the numerous possible embodiments of the invention. In particular, the transmission generator may depart from circularity and may for instance be a curve with a varying curvature. This possibility has an important effect on the shape of the definition generator.

Figure 11 illustrates a gear wherein the definition and transmission generators correspond to those of Figures 5 and 6. It will be seen that such a gear operating with a pure rolling motion and having a wide range of adjustment is by no means more complicated in its structure than the usual prior arrangements of the rotary roller type.

The bevel wheels 1 and 2 of the gear of Figure 11 are carried by shafts 6 and 8 journalled by main bearings 7 and 9 in a casing 10. On the shafts are spacing rings 18 and 19 for accurately locating the position of the wheels 1 and 2 with reference to the transmission rollers; and a thrust spring 11 produces the operating pressure. This can be replaced by a proportional pressure device or may be supplemented by such a proportional pressure device.

In accordance with the known art, the tilt axes *5a* and *5b* for the rollers are mounted in a pressure-balancing frame 14 held slidable perpendicular to the main axis of the gear by bolts 12 secured by nuts 13. Yokes *4a* and *4b* associated with the spindles of the transmission rollers *3a* and *3b* are adapted to slide in relation to shoes *21a* carried by the tilt axes *5a* and *5b*. Rods *20a* and *20b* rigid with the shoes prevent the shoes from coming off. At the centre of the gear are provided counter-bearings 15 and 16 connected with one another by a holder 17 and supporting the bevel wheels 1 and 2. The cost of construction corresponds to that of prior arrangements with the advantage, however, of a pure rolling motion and of uniform wear of the transmission rollers.

By reason of the pure rolling motion, it is possible to increase considerably the conformity factor or bearing of the parts against one another in the plane of the drawing, to the order of that used in present day grooved ball bearings or barrel-roller bearings. Thus an elongated pressure ellipse having a very long major axis is obtained. This gives a multifold increase in the load capacity of the contacting surfaces. It is thus possible to use a lower specific pressure, in other words, to omit hardening of the rolling surface. Owing to the avoidance of the evolution of heat and of the heat sensitivity of hardened surfaces, it is possible to abandon the use of a cooling-oil bath. The dry-running gear (the separate lubrication and sealing off the main bearings is not shown in the drawings) has a substantially higher frictional coefficent which moreover falls off very little when the peripheral speed increases. The improved frictional conditions open the possibility of running the gear at a higher speed, of building larger gears, and of obtaining higher throughputs for given sizes because both the torque that can be transmitted and the speed of rotation that can be used can both be greatly increased.

What I claim is:—

1. A change speed gear of the type set forth in which the definition generator of the bevel wheels and the transmission generator of the transmission roller or rollers are of such shape that the position of the operative contact points of the transmission roller or rollers with the friction wheels varies on the roller or rollers with the tilting thereof.

2. A change speed gear as claimed in claim 1 in which during tilting of the roller or rollers the wheels do not move axially but the or each roller is constrained to move in a curved path which correctly engages it with the wheels.

3. A change speed gear as claimed in claim 1 in which with the tilting of the transmission roller or rollers each about a stationary axis is associated a complementary movement either of the bevel wheels or of the transmission roller, depending on the law governing the shape of the operating surfaces of the wheels and rollers.

4. A change speed gear as claimed in claim 3 in which the complementary movement comprises a translational sliding of the axis of the transmission roller perpendicular to itself in the manner known for pressure compensation, or a rocking movement of the transmission roller about an axis through the centre of the roller and parallel to the axis about which the roller is tilted.

5. A change speed gear as claimed in any of the preceding claims, in which the operative diameter of the transmission roller increases when the roller is tilted away from its mid-position.

6. A change speed gear of the type set forth or as claimed in any preceding claim in which at all adjustments the tangents to the points of contact between the bevel wheels and the transmission roller pass through the intersection of the axes of the wheels and roller.

7. A change speed gear as claimed in any preceding claim in which the curvature of the definition generator varies con-

tinuously while the transmission generator is constituted by a circular arc.

8. A change speed gear as claimed in claim 7 and having the translational sliding of the axis of the transmission roller specified in claim 4 in which the said translational sliding is obtained by causing a point on the axis of the transmission roller to follow the circular arc which approximates to the true, cycloid-like curve, said arc having its centre somewhat nearer the axis of the bevel wheels than does the centre of the transmission generator at mid position.

9. A change speed gear as claimed in claim 8 in which the translational sliding is effected by the rolling of a flat bearing surface on the end of the roller shaft, on the surface of a freely rotatable shaft the surface of which constitutes the circular arc approximating to the true curve.

10. A gear as claimed in any of claims 1 to 6 in which the curvature of the definition generator and also of the transmission generator both vary continuously.

11. The several constructions of change speed gear of the type set forth and means for drawing the definition generators thereof substantially as described with reference to and as shown in the accompanying drawings.

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Fig. 1

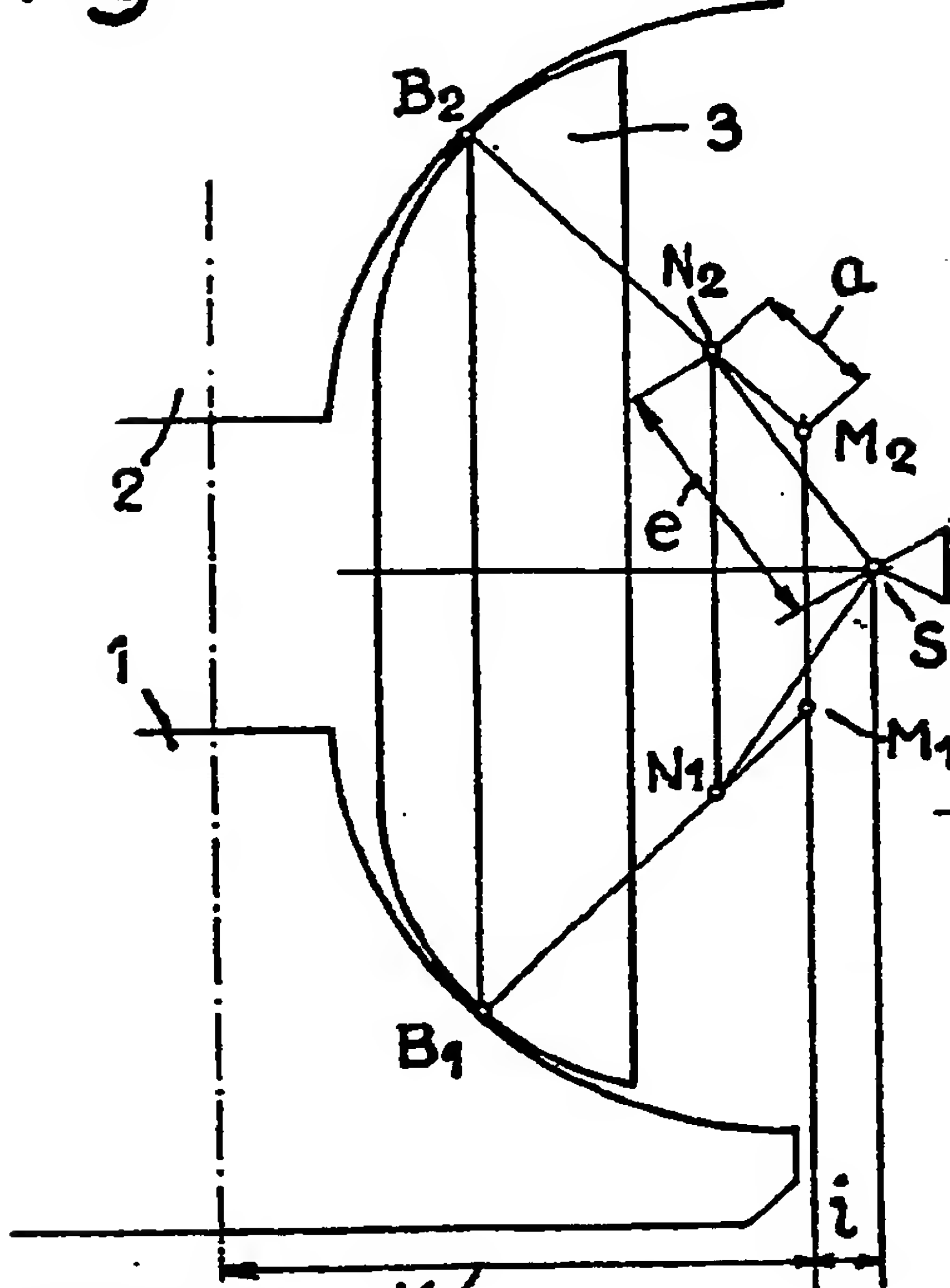


Fig. 2

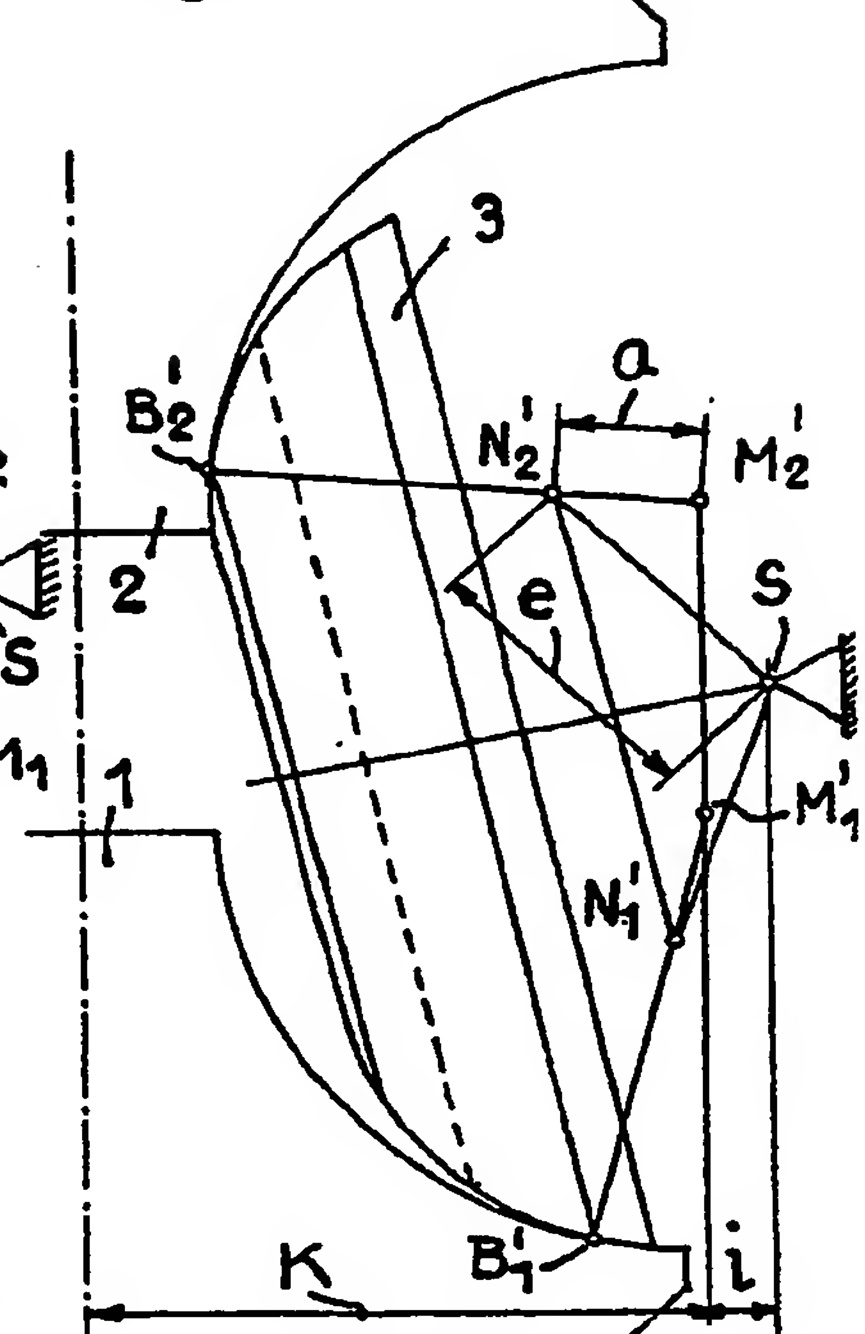


Fig. 7

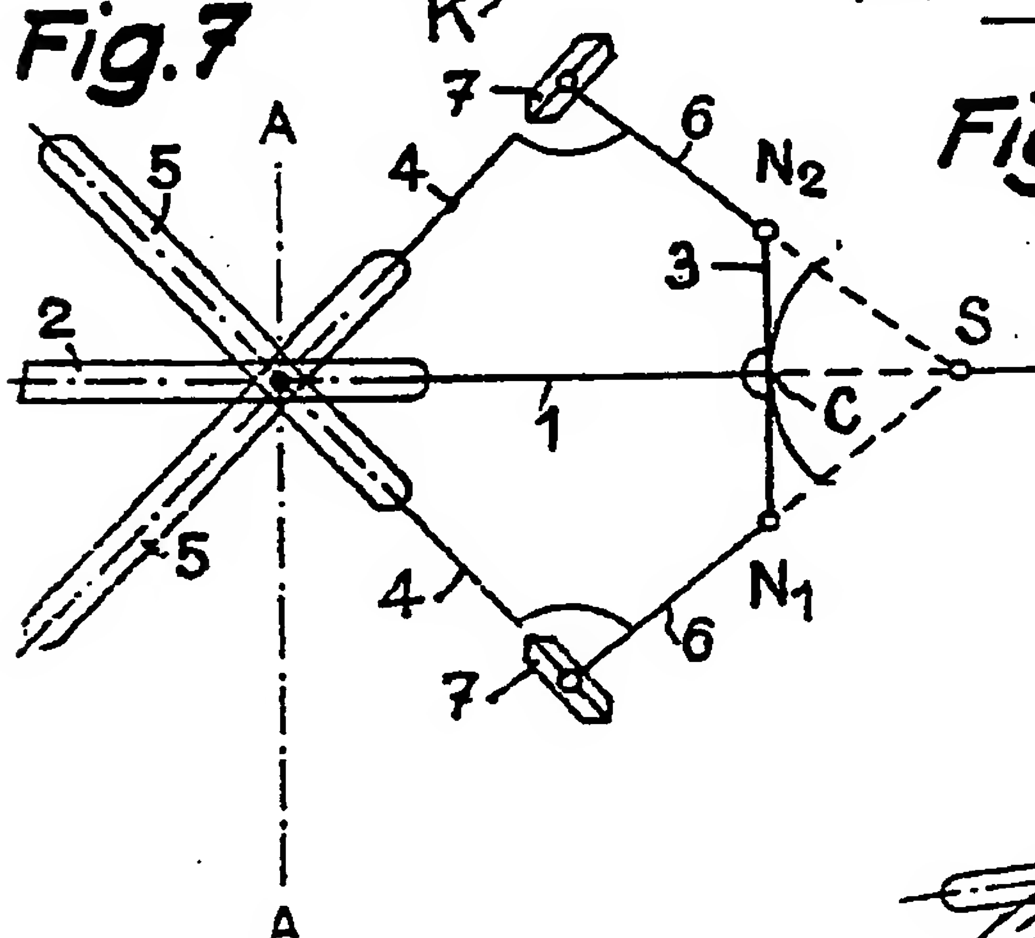
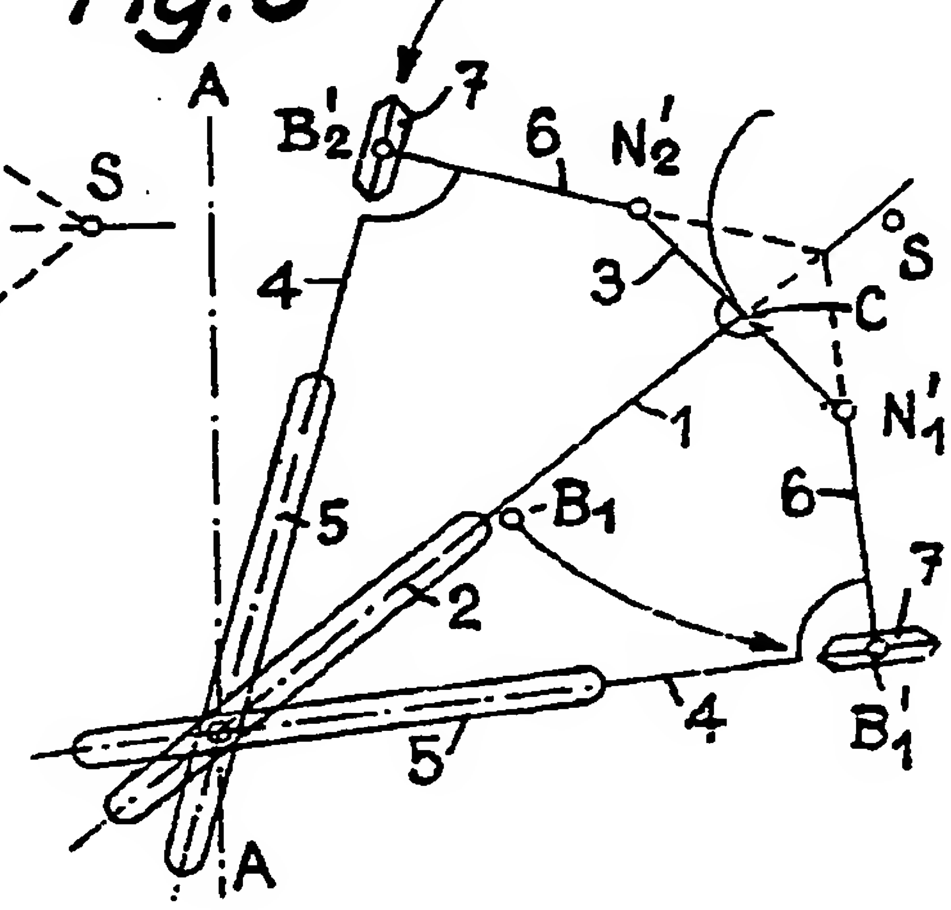


Fig. 8



673,168 COMPLETE SPECIFICATION
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SHEETS 1 & 2

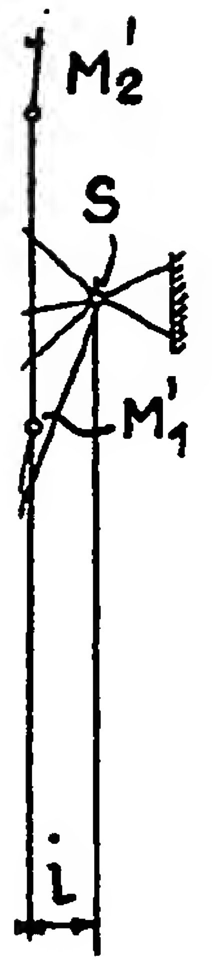


Fig. 3

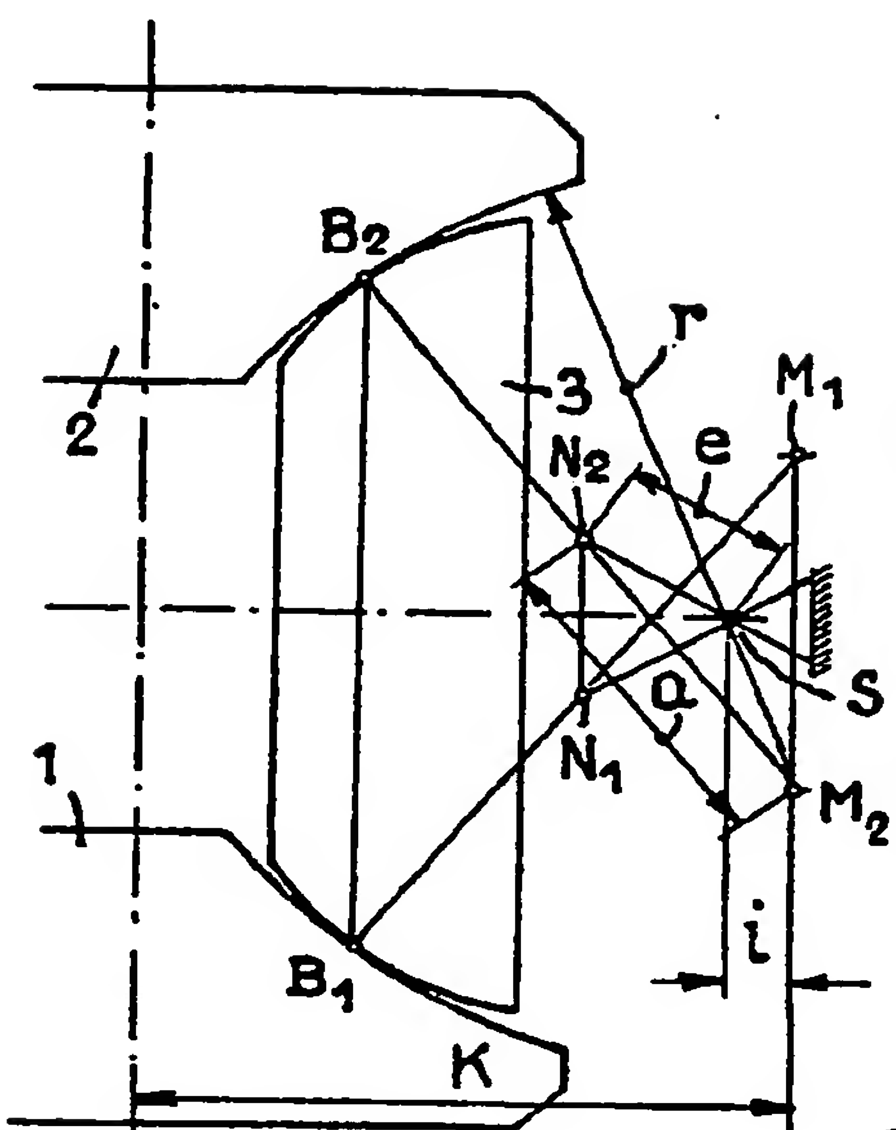


Fig.4

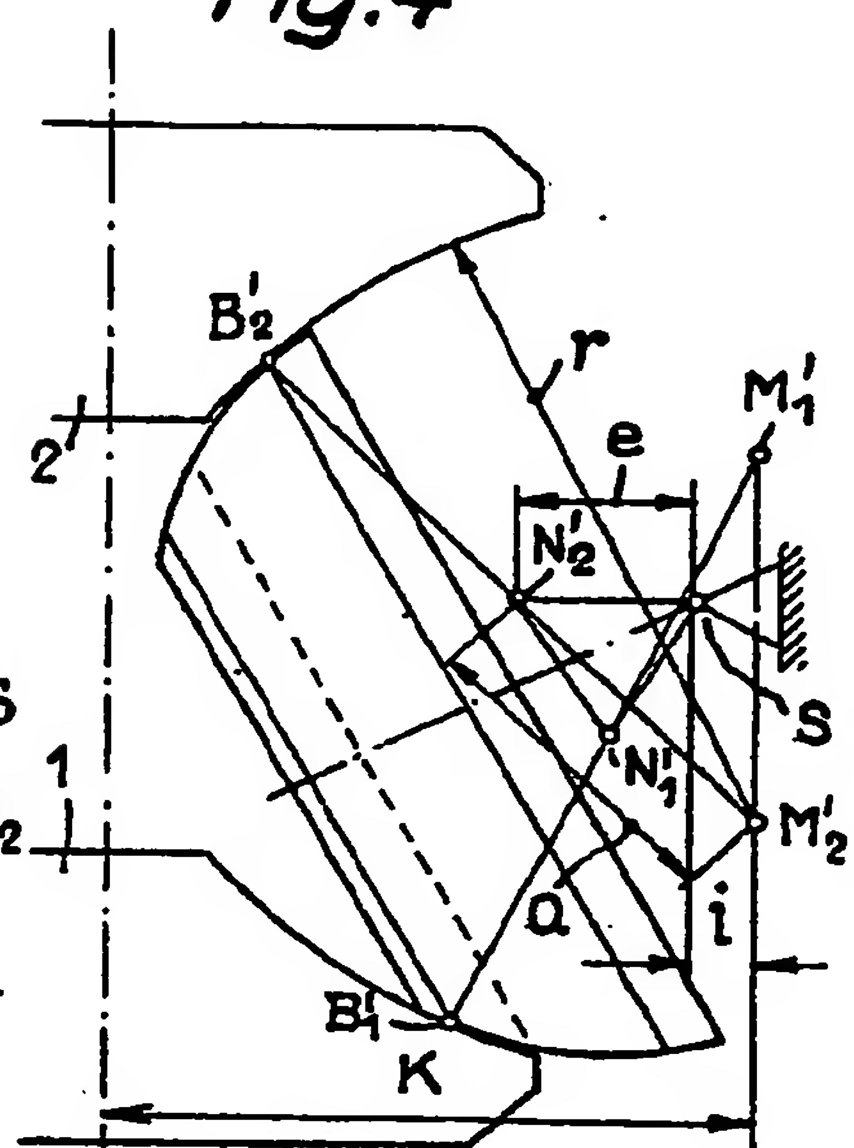


Fig.5

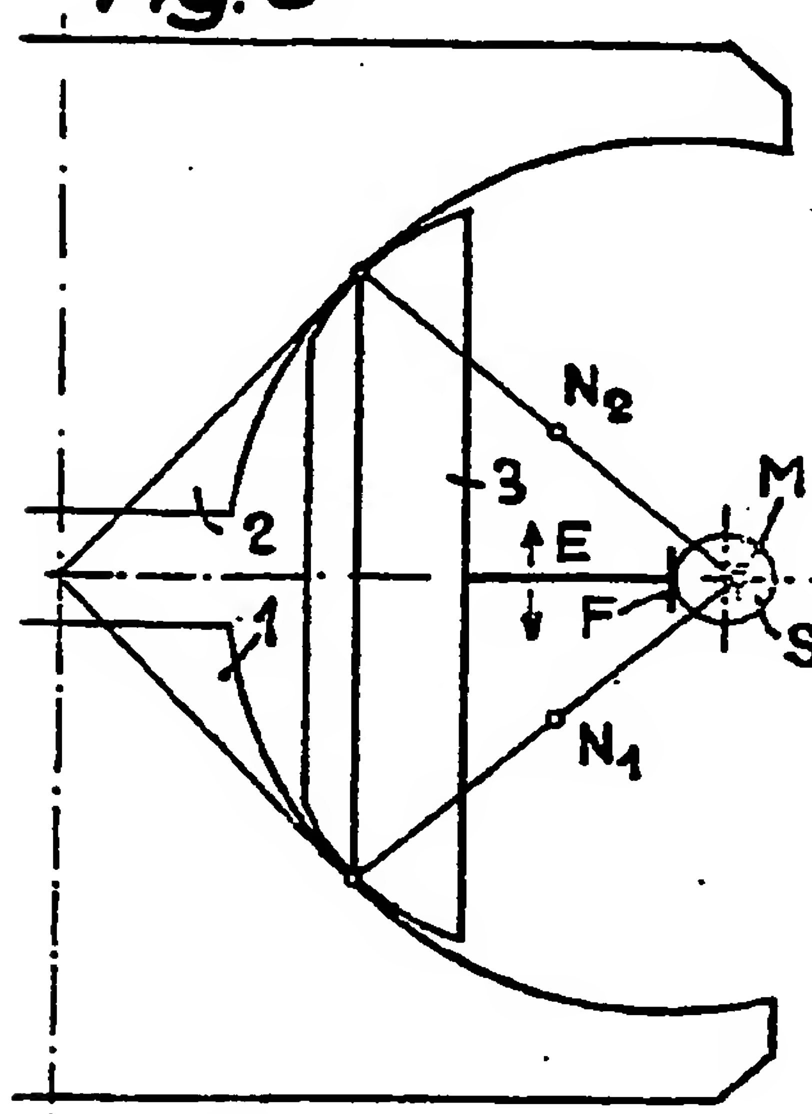
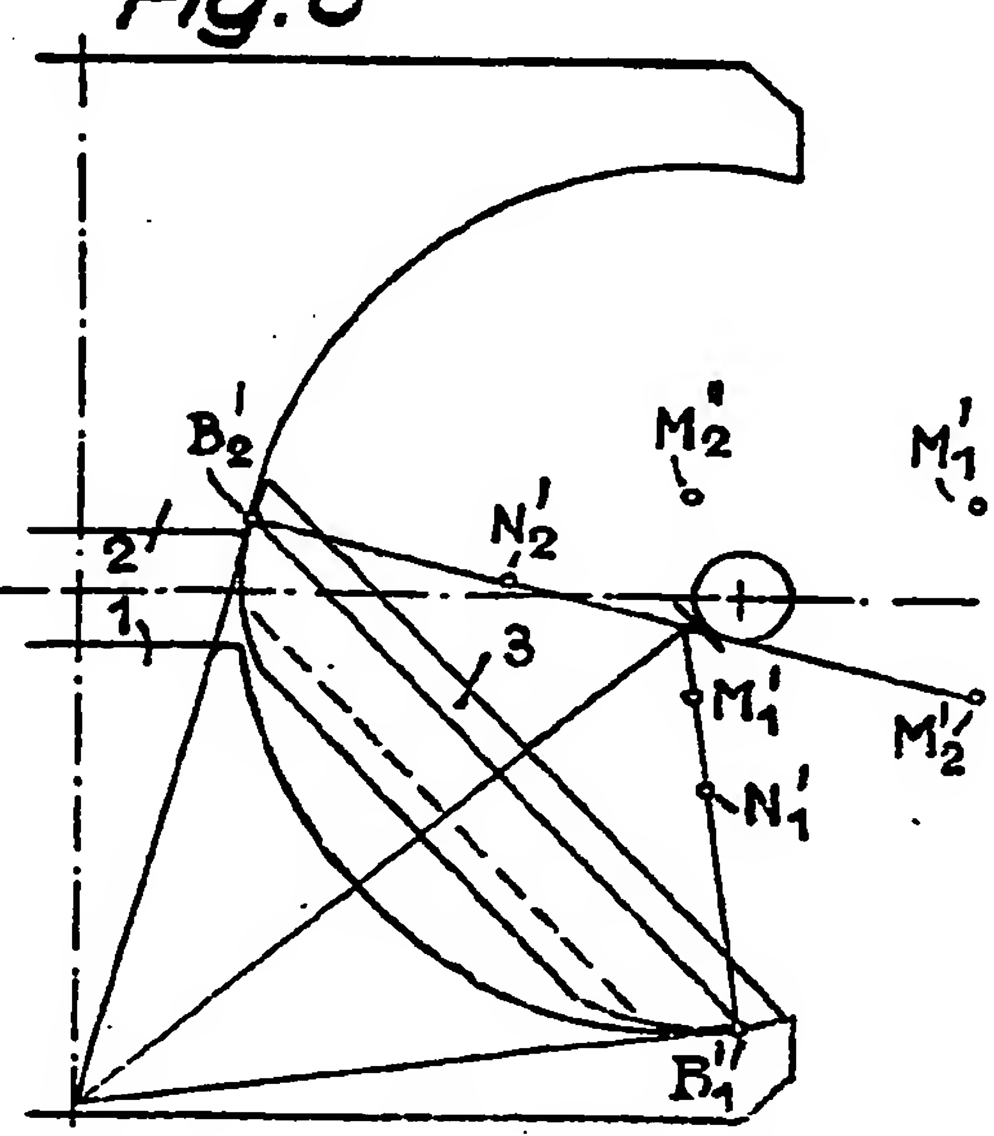
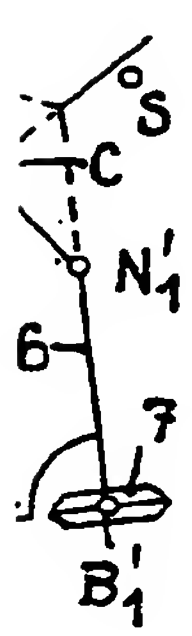


Fig.6





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SHEETS 1 & 2

Fig. 1

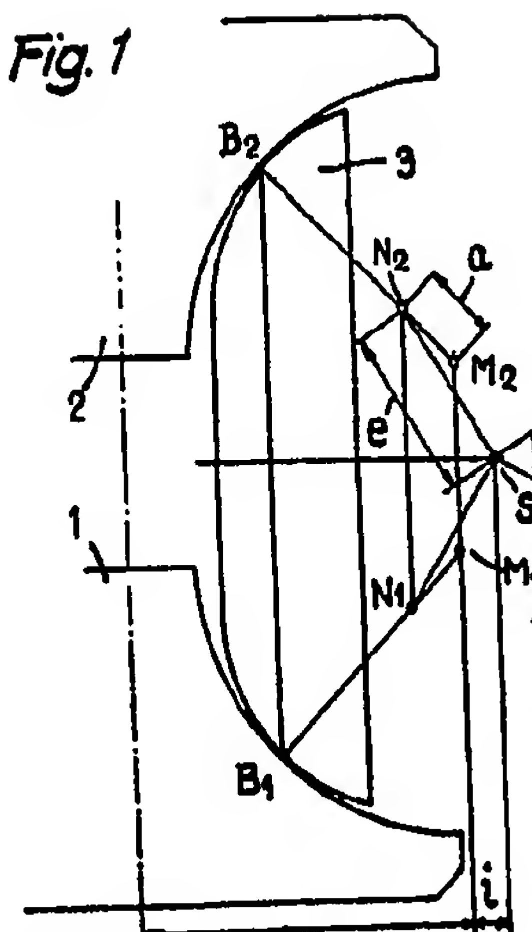


Fig. 2

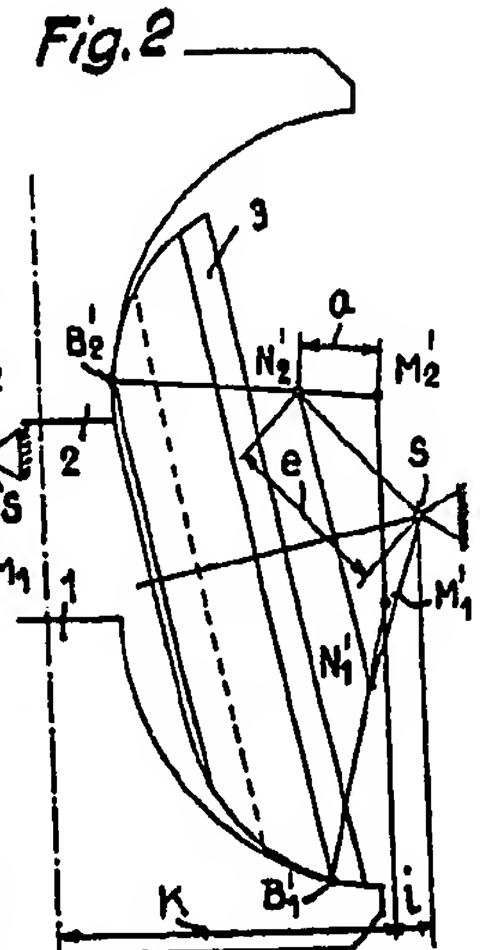


Fig. 3

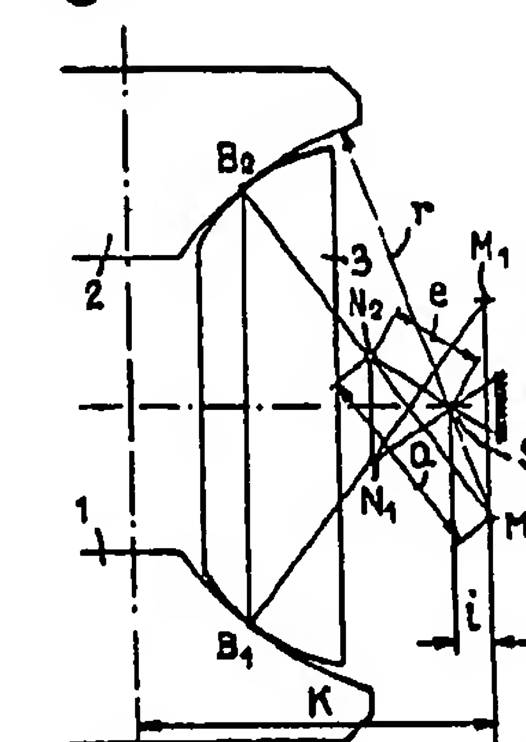


Fig. 4

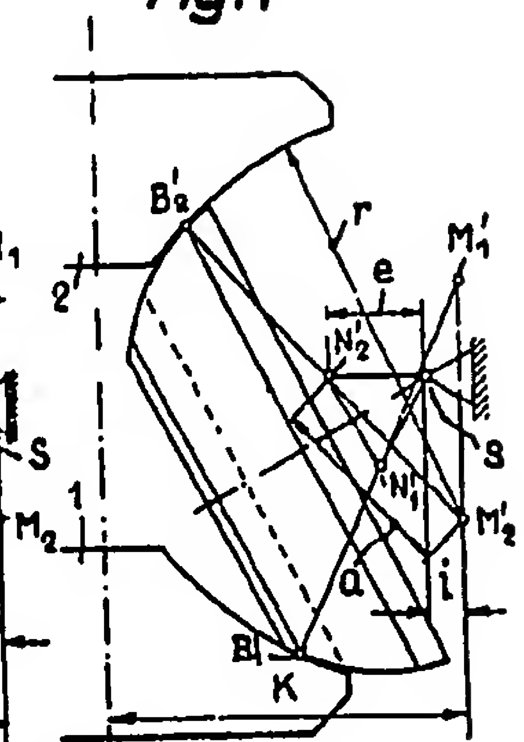


Fig. 7

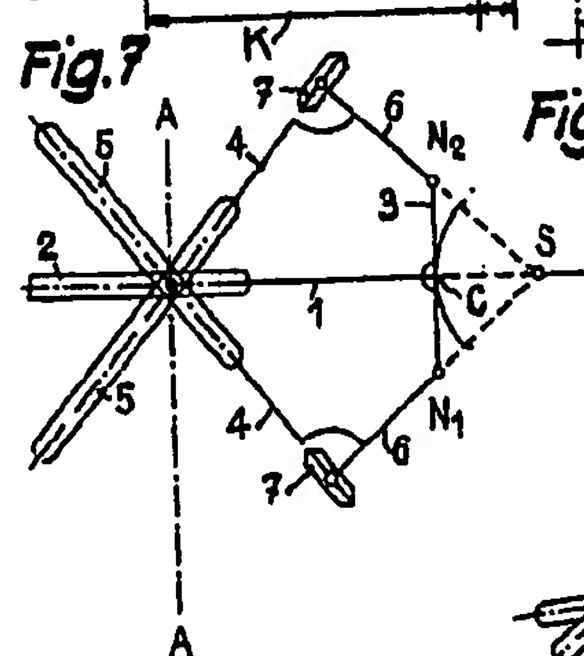


Fig. 8

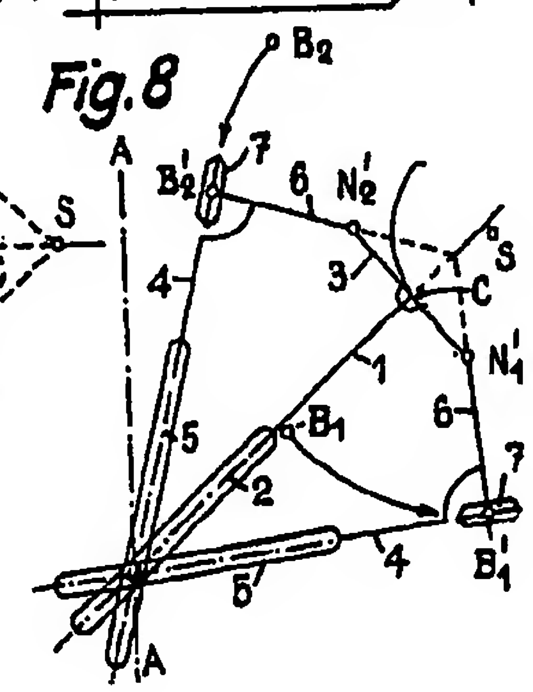


Fig. 5

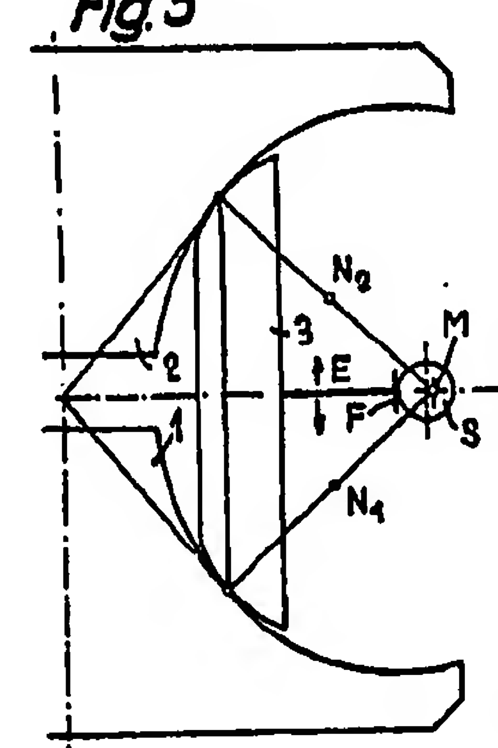


Fig. 6

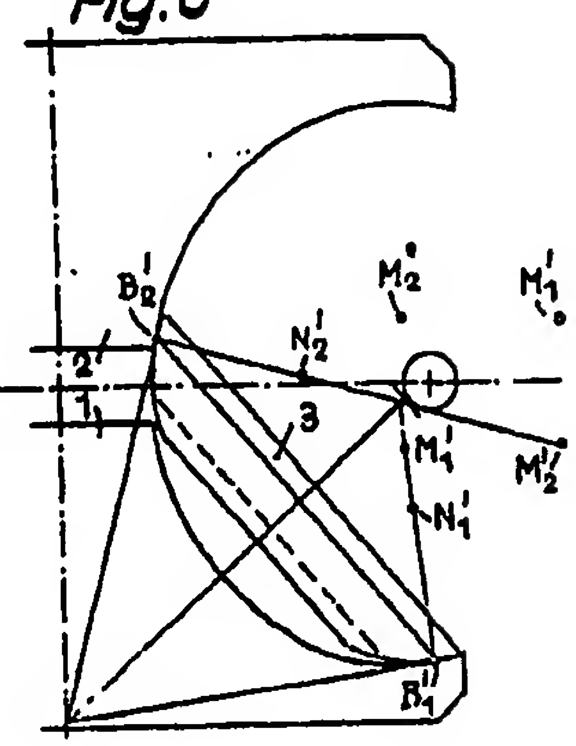


Fig. 9

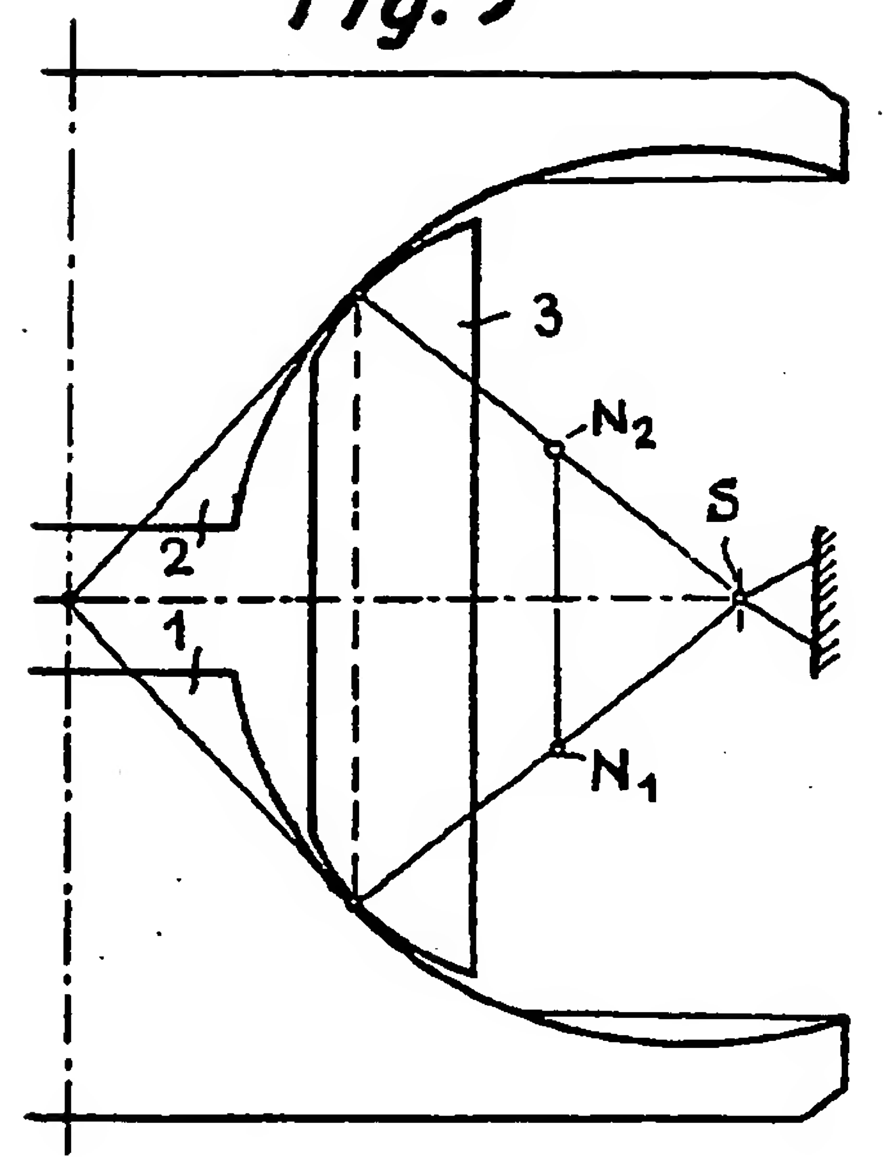
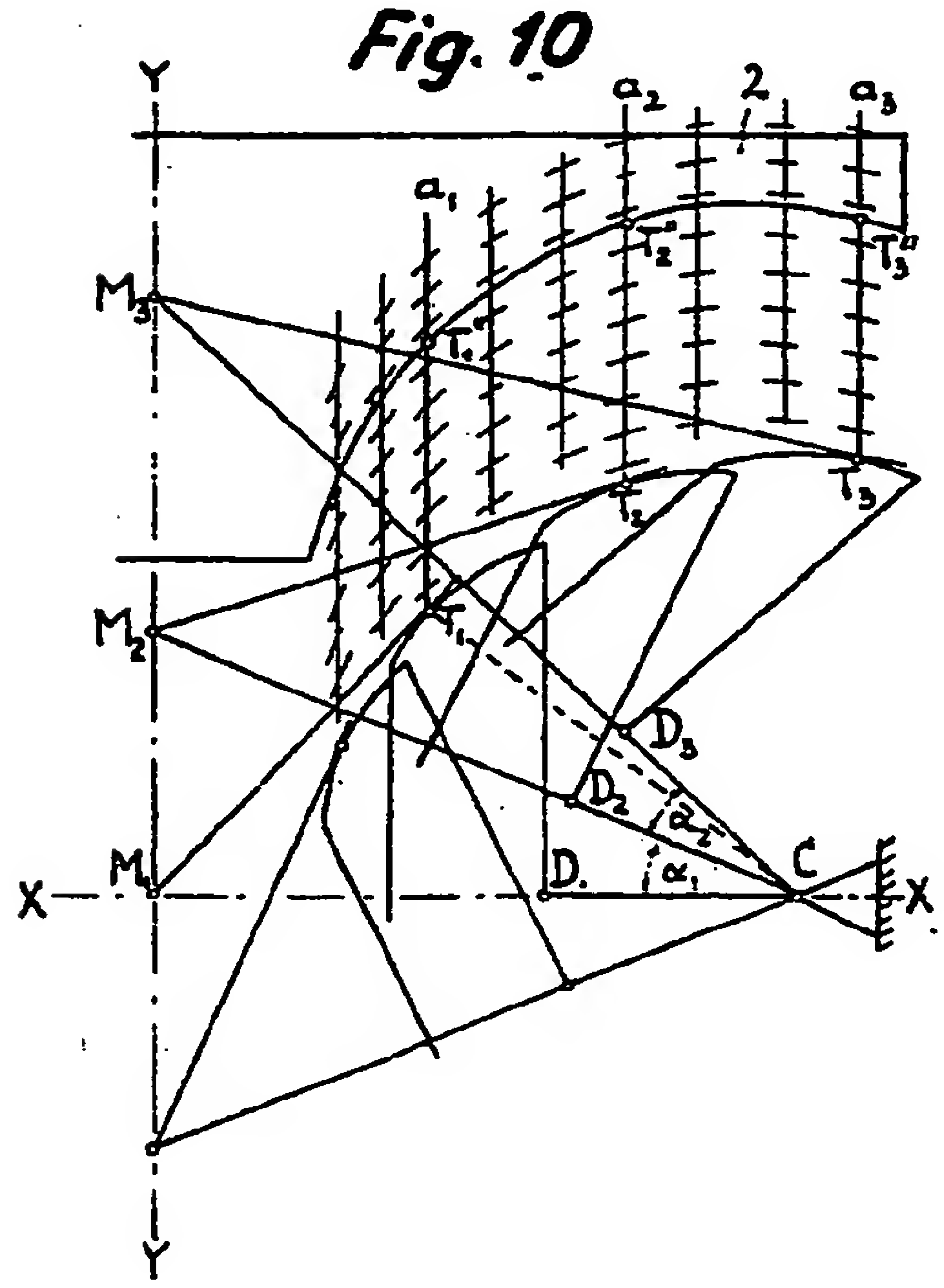

3
N_2
S
2
1
N_1

Fig. 10


Y
a_2
2
a_3
a_1
M_3
T_1'
T_2'
T_3'
T_2
T_3
M_2
T_1
D_3
D_2
α_2
X
M_1
D
α_1
C
X
Y

6

673,168 COMPLETE SPECIFICATION
4 SHEETS

This drawing is a reproduction of the Original on a reduced scale.

SHEETS 3 & 4

Fig. 11

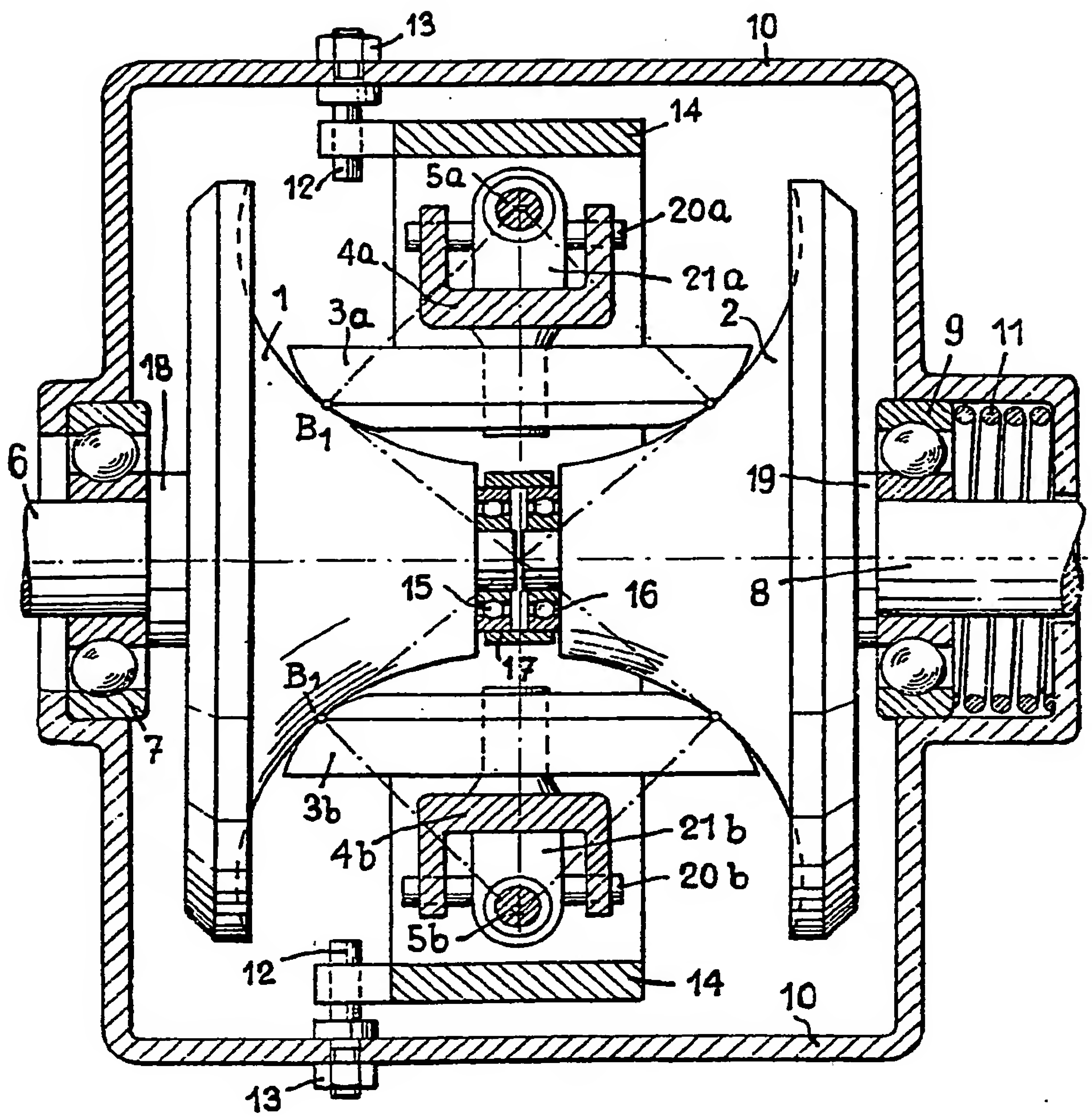


Fig. 9

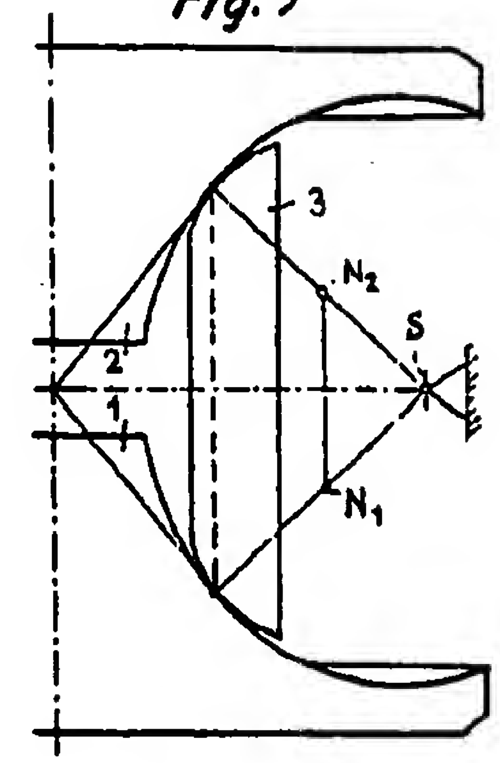


Fig. 10

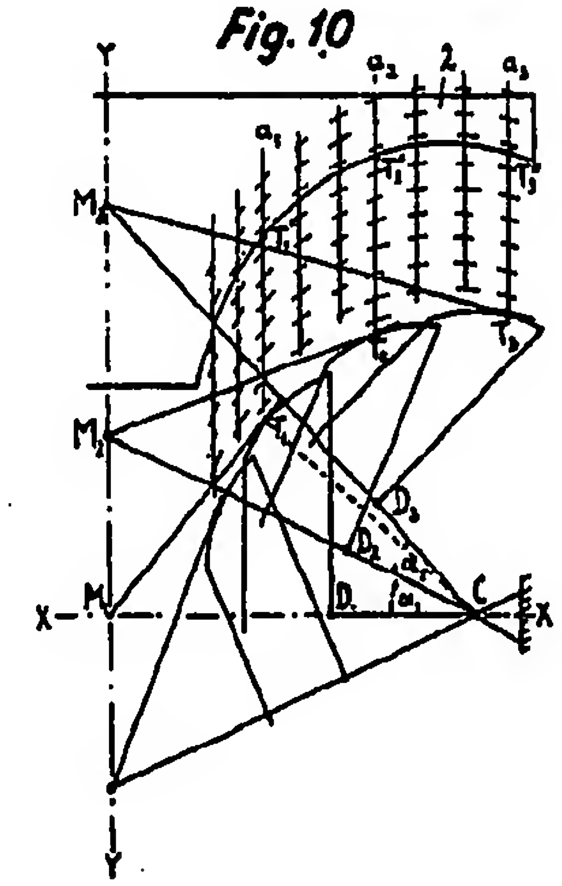


Fig. 11